

## **SuperTruck – Development and Demonstration of a Fuel-Efficient Class 8 Tractor & Trailer *Vehicle***

DOE Contract: DE-EE0003303

Project Officer: Ralph Nine

Project Manager: Roland Gravel

Navistar Principal Investigator: Russ Zukouski

DOE MERIT REVIEW

06 /09 /2016

Project ID: VSO064



## Timeline

Project Start:	October 2010
Project End:	Sept 2016
% Complete:	91%

## Partners

<b>Navistar</b>	Principal Investigator, Vehicle Systems Integrator Controls Systems, Engine & Vehicle Testing
<b>Bosch</b>	Fuel Systems
<b>Wabash</b>	Trailer Technologies
<b>Argonne ANL</b>	Dual Fuel Engine testing, simulation & evaluation
<b>Lawrence LLNL</b>	Aerodynamic CFD

## Barriers

- Achieving 50% freight efficiency while balancing Voice of Customer Needs
- Alignment with business needs
- Reducing tractor weight while adding new systems

## Budget

Total Funding:	\$76,178,386
DOE:	\$35,754,460
Prime:	\$40,423,926
Funding FY2015	\$8,965,646
Funding for FY2016	\$4,896,000

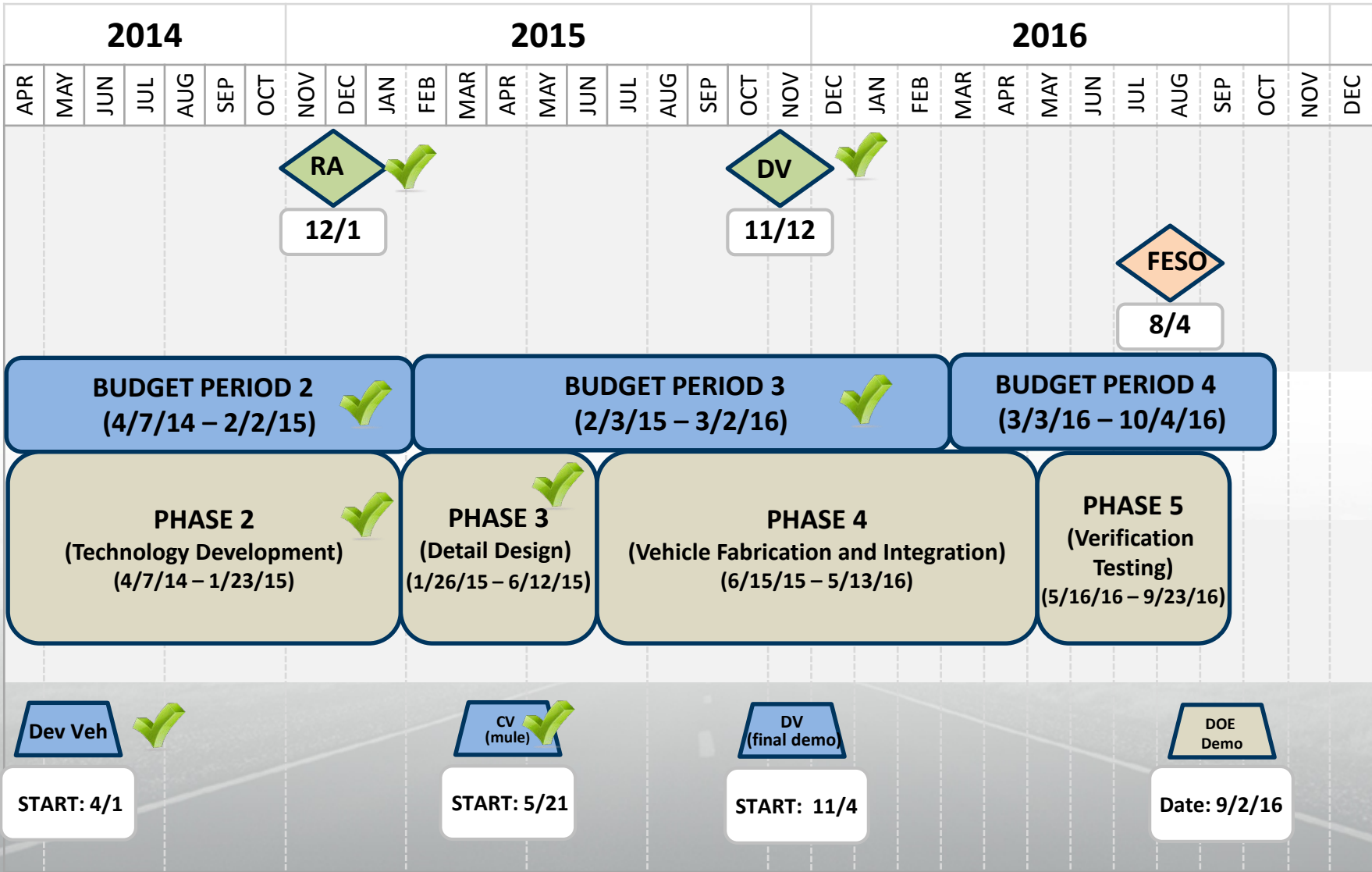
- Project Goal

- Demonstrate 50% improvement in freight efficiency of a combination Tractor-Trailer
- Attain 50% BTE Engine
- Demonstrate path towards 55% BTE Engine

- March 2015 to March 2016 Goals


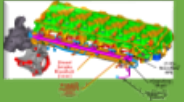
- ✓ – Ramp up program to meet compressed deadlines
- ✓ – Optimize technology for best results
- ✓ – Build & evaluate mule truck T3
- ✓ – Complete Phase 3 (*concept phase/ technology roadmap*)

# Program Timing



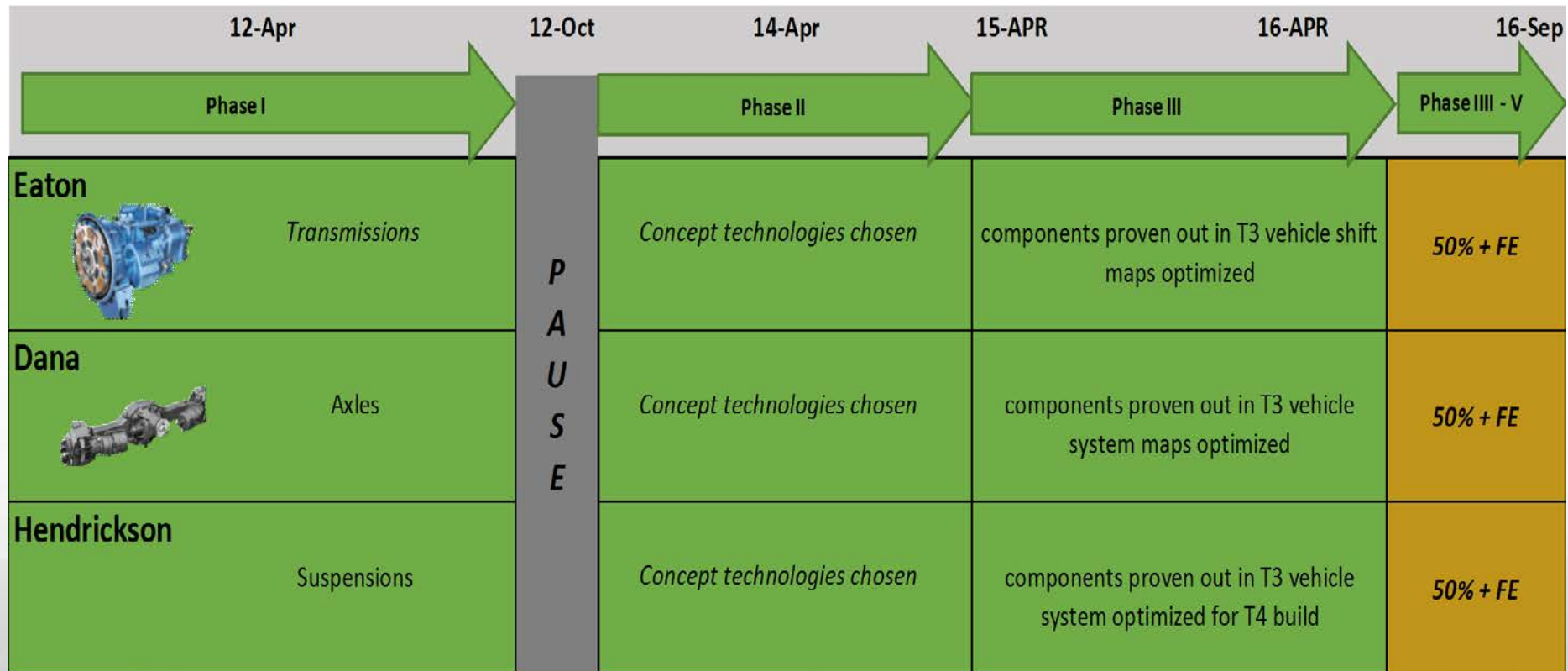
# Vehicle Partnerships and Completed tasks



12-Apr		12-Oct	14-Apr	15-APR	16-APR	16-Sep
Phase I			Phase II	Phase III		Phase III - V
 <b>Navistar</b> <i>Vehicle systems integrator Control Systems Base Engine</i>		<b>P A U S E</b>	<i>Concept technologies chosen 48.3% BTE achieved Load biasing evaluated Material procured for Mule build Engine Design Controls deployment</i>	<i>T3 Vehicle achieved 70% FE 48.9% BTE achieved Load biasing concluded in final build Material procured for Mule build Engine Design Controls deployment</i>		<b>50% + FE</b>
			<i>Trailer Design</i>	<i>Trailer and system built</i>		<b>50% + FE</b>
			<i>Adv comb with FIS strategies</i>	<i>Adv comb with FIS optimization complete WHR system developed</i>		<b>50+ BTE Path 55% BTE</b>
			<i>Computational Fluid Dynamics</i>	<i>Speed form complete wind tunnel testing Final body shape in procurement</i>		<b>50% + FE</b>
 <b>ANL</b> <i>Engine Design Controls deployment Fuel Reactivity testing</i>			<i>VVA 1D/3D simulations Reduction of Parasitic Fuel Reactivity testing</i>	<i>VVA evaluated 1D/3D simulations Reduction of Parasitic demonstrated Fuel Reactivity testing in final stage</i>		<b>50+ BTE Path 55% BTE</b>

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# Vehicle Collaborators & Completed tasks





# 2015-16 Focus

## Four Distinct Areas of Progress

### Lightweighting

- Lightweight Frame
- Composite Materials
- Lightweight Trailer

### Rolling Resistance

- Energy Recovery
- Reduced Parasitic

### Aerodynamic Improvement

- Tractor
- Trailer

### Powertrain Technologies

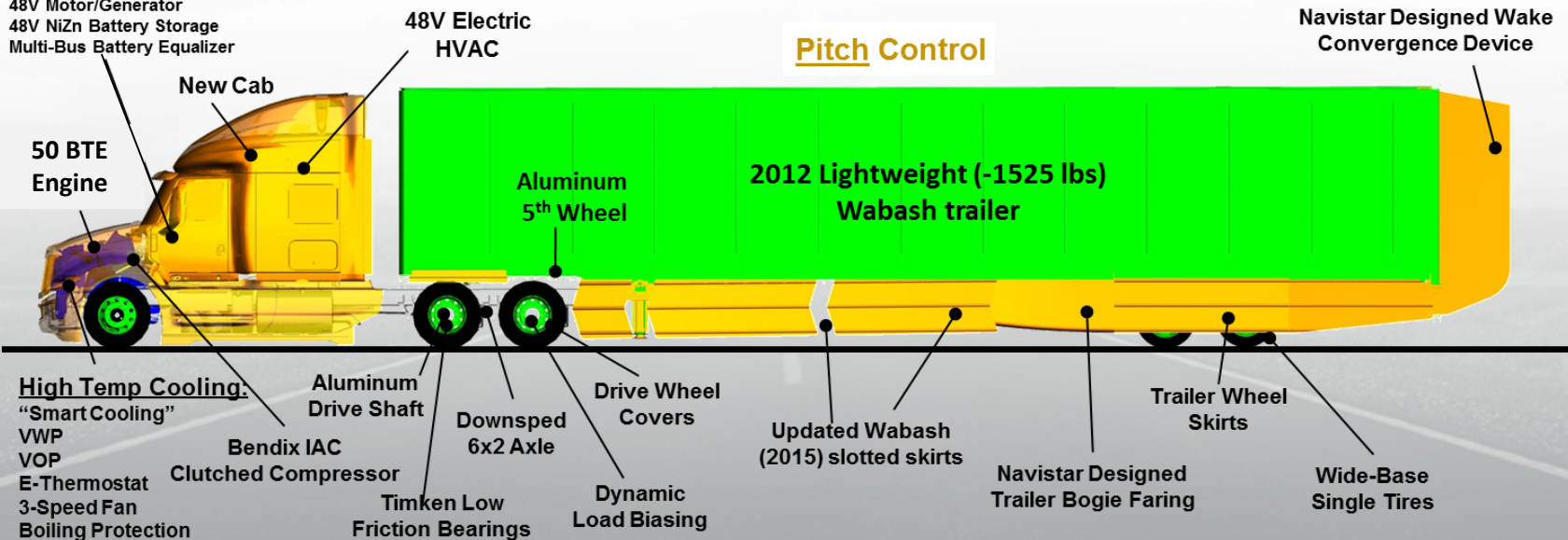
- High Efficiency Drivetrain
- Stop/Start Idle Reduction
- Waste Heat Recovery
- eTurbo
- Adv. Aftertreatment
- Friction Reduction

#### Recuperative Electric Charge:

"Smart Charging"  
48V Motor/Generator  
48V NiZn Battery Storage  
Multi-Bus Battery Equalizer

### Technology road map developed

#### Pitch Control

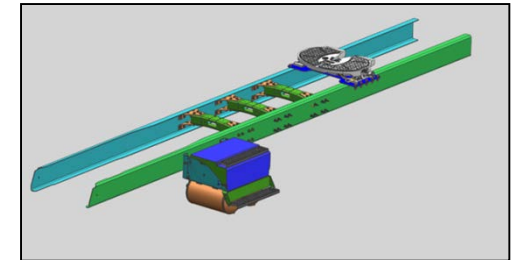


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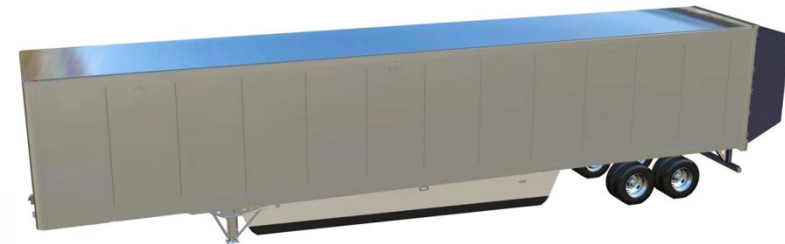
# Weight Reduction



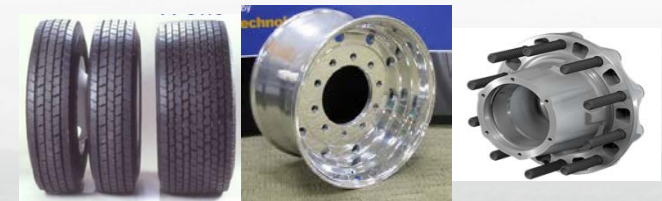
- Frame System ( Target:  $\sim 0.96\%$  FE )
  - Frame w/ Lightening Holes (Demonstrated)
  - Aluminum Cross Members (Demonstrated)
  - NiZn Batteries (Lead Acid) Battery Box (May Demonstration)
  - Aluminum Fixed Position 5<sup>th</sup> Wheel (Production)



- Wabash National Trailer (  $\sim 5.1\%$  FE )
  - Lightweight Trailer (Demonstrated)
  - Aerodynamic Skirts (Demonstrated)
  - Axle Bogie Treatment (Demonstrated)
  - Boat Tail (Demonstrated)



- Tire & Wheel Equipment ( $\sim 1.81\%$  FE )
  - Wide Base Single Rear Tires (Demonstrated)
  - Aluminum Rims/Hubs (Demonstrated)
  - Timken Bearings and Uprights (Demonstration)
  - Steel Shell Brake Drums (Production)



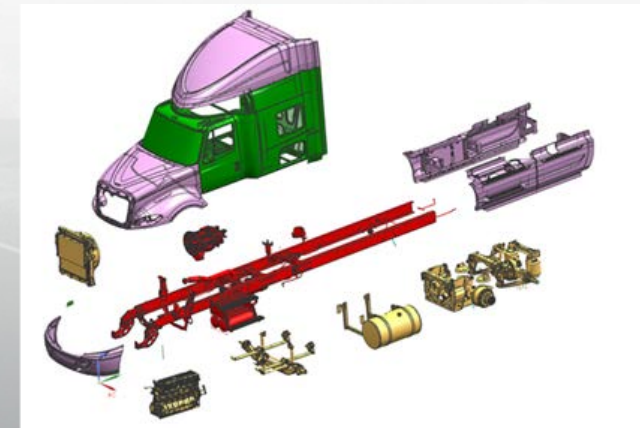
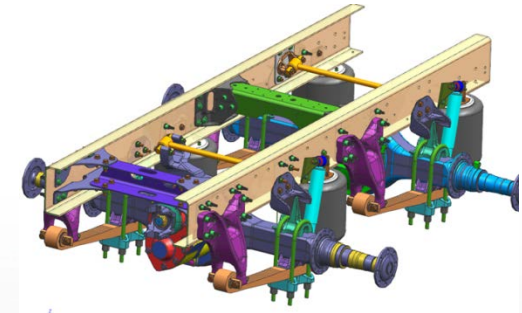
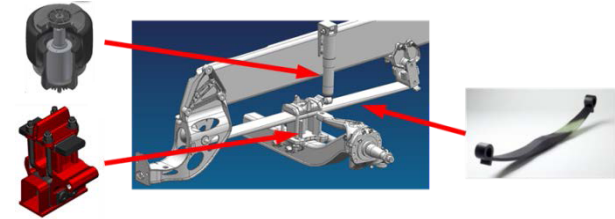
- Lightweight Driveshafts and Axles ( 1.83% FE )
  - 6x2 Configuration (Demonstrated)
  - "Diamond Series" Aluminum Driveshaft (Production)



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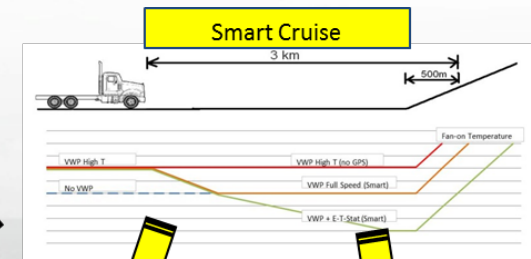
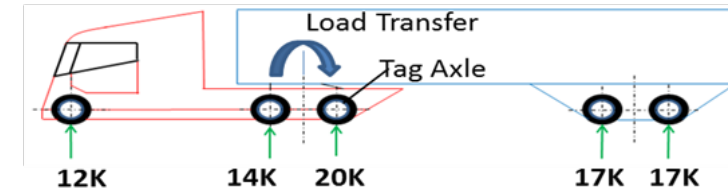
- Hybrid Front Suspension ( ~0.41% FE )
  - Aluminum Components (Demonstrated)
  - Composite Leaf Springs (Demonstrated)
  - Integration w/ Hendrickson STEERTEK NXT (Production)
- Lightweight Rear Suspension ( ~0.52% FE )
  - Redesign (Demonstrated)
  - Aluminum Crossmembers (Demonstrated)
- Cab ( ~10.5% FE )
  - Weight Reduction (Demonstration)
    - Composite Sidewalls & Closures
    - Cabinets/Interior
    - Composite Skirt Support Structure
    - Light Weight Hardware



# Rolling Resistance, Parasitic Reductions & Drivetrain



- Rolling Resistance ( ~7.2% FE )
  - Wide-Base Single Tires (**Demonstrated**)
  - Timken PDFE Bearings (**Demonstrated**)
- 6x2 Drivetrain ( ~3.0% FE )
  - 6x2 Configuration (**Demonstrated**)
  - Direct-Drive Eaton UltraShift (**Demonstrated**)
  - Load Biasing Suspension (**Demonstrated**)
- “Smart” Subsystems (~6.6% FE )
  - Cruise Control (**Demonstrated**)
  - High Temp Cooling (**Demonstrated**)
  - Air Compressor (**2016 Demonstration**)
  - Alternator /Generator (**Sept. Demonstration**)
  - A/C compressor (**2016 Demonstration**)



Integrated Air Compressor



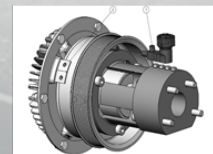
48 Volt Motor/Generator



48 Volt A/C compressor



3-speed Fan Drive



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## SuperTruck (T3) – Gate 3 Demonstration Testing

September 2015



T3-Supertruck Mule

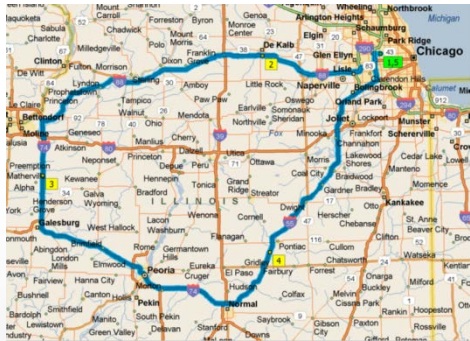
Baseline Prostar

Gross Vehicle Weight (lb)	
Total	64,600
Tare	32,780
Payload	31,820

Gross Vehicle Weight (lb)	
Total	64,680
Tare	33,220
Payload	30,600

4% Freight Efficiency Improvement (Payload)

### Illinois Flatlands Testing (Type IV – Fuel Economy)



- Ave. 10.45 MPG (@ 64,600lbs)  
(10.44, 10.44, 10.58)
- 64.5% increase vs. 2009 Prostar

**Simulated T3 Composite Freight Efficiency Improvement = 70%**

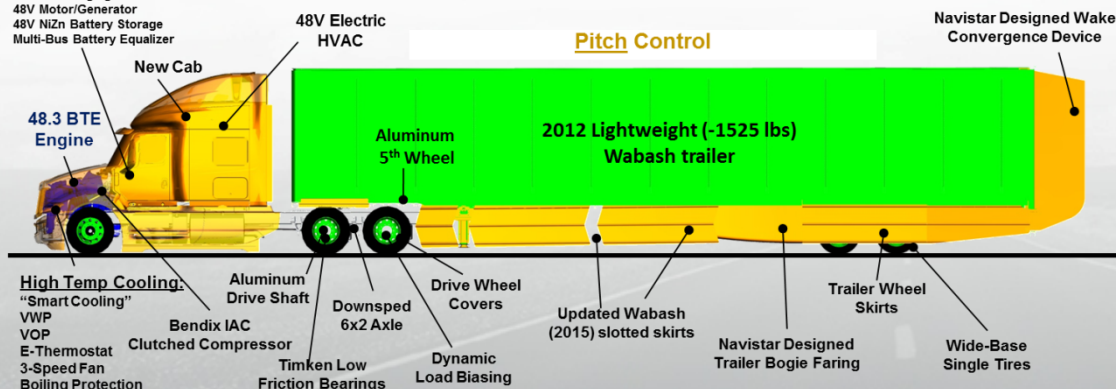
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- ✓ 1. Several aerodynamic scale-models have been developed and evaluated in the wind tunnel. Significant improvement over the baseline vehicle has been observed which will be incorporated in final design
- ✓ 2. Initial load biasing evaluation completed
- ✓ 3. Concept material has been procured for mule vehicle test
- ✓ 4. Current engine tested at a BTE of 48.3% with additional technologies still to deploy
- ✓ 5. Technology concepts & targets established to move forward to Phase 3 (Design)

## ✓ Recuperative Electric Charge:

"Smart Charging"  
48V Motor/Generator  
48V NiZn Battery Storage  
Multi-Bus Battery Equalizer



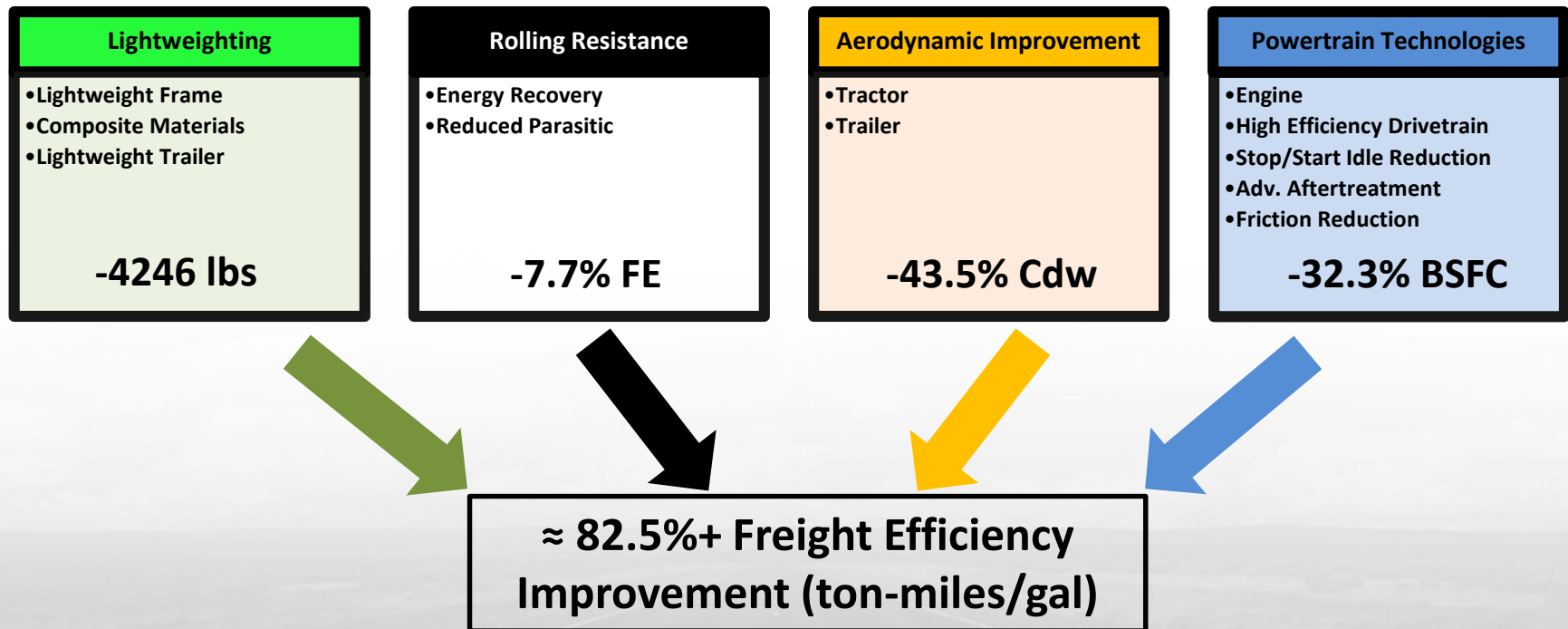
Development Area	Freight Efficiency Target
Weight	65+
Rolling/Parasitic	
Aerodynamics	
Engine	

1. Calculated, simulation, or test data
2. Improvements shown relative to SuperTruck mule vehicle

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# T4 Vehicle Technical Approach

## Four Distinct Areas of Development

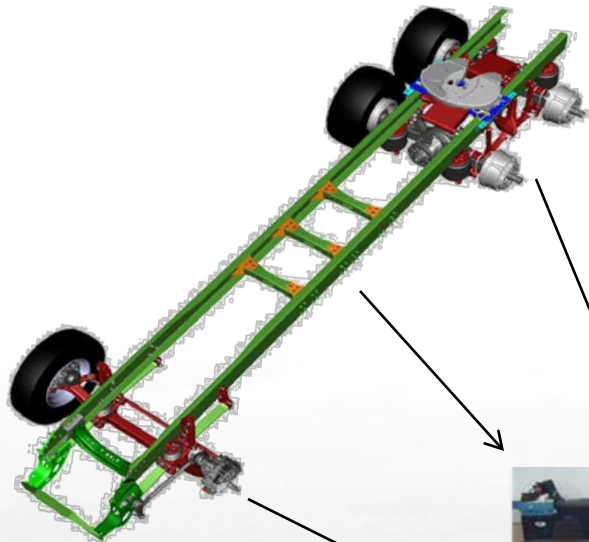


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# Chassis Build



2015			2016								
October	November	December	January	February	March	April	May	June	July	August	September
Chassis Procurement			Chassis Build				Commission				



- Frame Rails  
( 0.3% FE)
- Aluminum Cross Members  
( 0.1% FE)
- Hybrid “Leaf over Spring” Front Suspension  
( 0.4% FE)  
Composite Leaf Springs  
Air Disk Brakes
- 6x2 Rear Suspension  
HTB light Suspension  
( 0.9% FE)  
Weight Reduced-1.91 RAR  
(0.1% FE)  
Weight Reduced Tag Axle  
( 0.2% FE)
- Aluminum 5th Wheel  
(0.3% FE)
- Next Gen Michelin Tires  
(0.3% FE)

1.) 13% FE improvement



Additional 2.5% FE\*  
\* vs. T3 Demo Vehicle



# Powertrain Build / WHR Timing

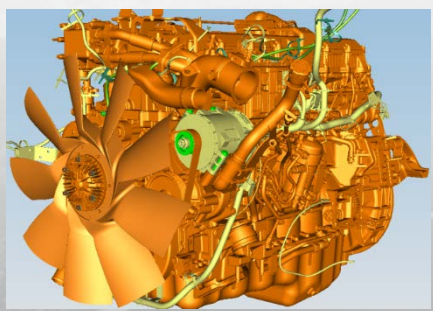
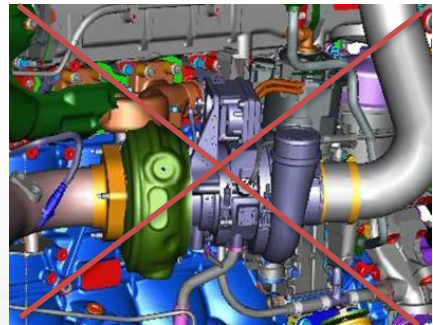
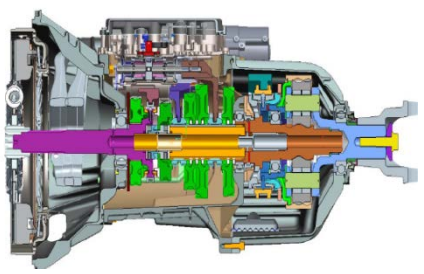


2015			2016								
October	November	December	January	February	March	April	May	June	July	August	September
WHR Test	WHR Design/Packaging	Powertrain Procurement			Powertrain Build		Commission	Calibration			

Nov. 1  
WHR Decision:  
eTurbo and/or ORC



April  
Eaton 12 Speed EN3  
Delivery



- Final Supertruck Engine (50 % BTE)  
(-9.2 BSFC)
  - Weight Impact:  
Base Engine (TBD)  
WHR (TBD)  
Transmission (-0.6% FE)
- Additional 10% FE\***
- \* vs. T3 Demo Vehicle

# SuperTrailer Build Schedule



	2016					
	December	January	February	March	April	May
Trailer						
Solar Panels						
Boat Tail						
Bogie Fairing						
Close-Out Panel						
Front Face Fairing						
Skirts						



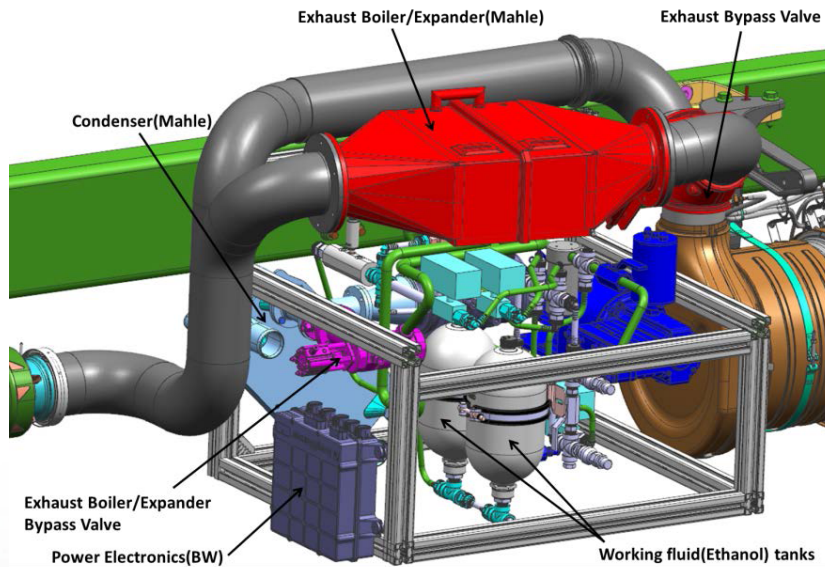
- Trailer Weight Reduction:  
(1.7% FE)
  - Trailer Aero Improvement:  
(7.2% FE)
- Additional 9% FE\***  
\* vs. T3 Demo Vehicle



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FE = Freight Efficiency (ton-miles/gal)

# Final SuperTruck Design/Build Status (Waste Heat Recovery)



## Technology Updates:

### Exhaust ORC energy Recovery System

- Ethanol Working Fluid
- Exhaust Bypass Configuration
- Frame Mounted
- Borg Warner Turbine/Generator
- 48Volt power to Motor/Generator or Storage

## Performance Metrics:

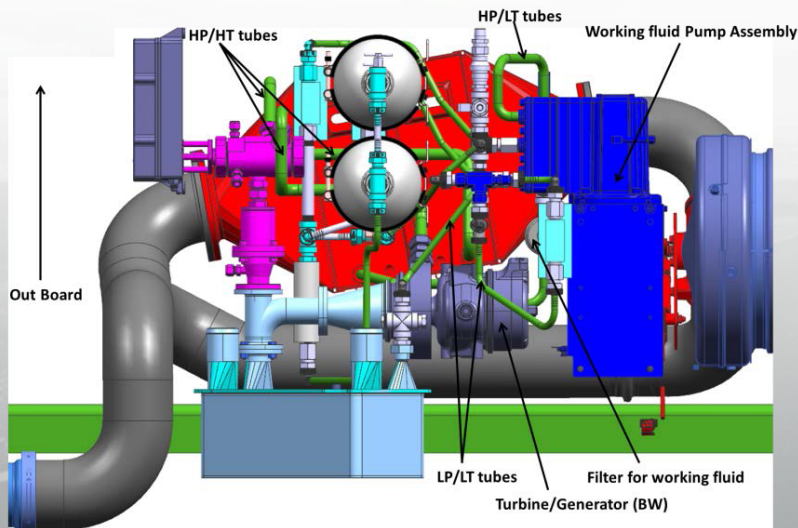
- 1 to 4 kW capability
- Target ~1.2% BTE gain

## Build Status:

Chassis Mount Design Freeze (12/9/15)

ORC Design Freeze (1/31/16)

Assembly (3/7/2016)



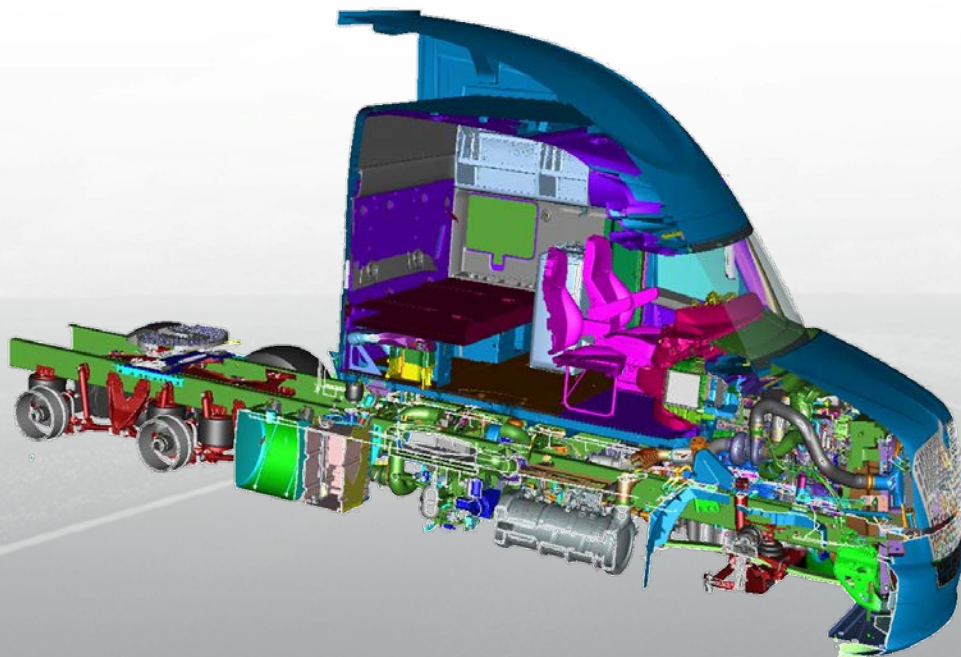
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# Timing for T4 Vehicle build of SuperTruck



2015			2016								
October	November	December	January	February	March	April	May	June	July	August	September
Chassis Procurement ✓			Chassis Build ✓				Commission				
Cab Procurement ✓					IP & Trim ✓		Cab Drop				
WHR Test ✓	WHR Design/Packaging ✓	Powertrain Procurement ✓				Powertrain Build ✓	Commission	Calibration			
	Accessory Design ✓	Accessory Procurement ✓			Acc. Build ✓		Commission	Strategy Develop.			



Design
Procurement
Build
Test
Documentation

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